

SYNOPTIC DESCRIPTION OF THE 5577 Å NIGHTGLOW
NEAR 78° WEST LONGITUDE

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ABSTRACT

This paper describes the diurnal and latitudinal variations in the 5577 Å zenith nightglow intensity, as observed during a shipboard expedition along the Pacific coast of South America. These results show good agreement with a similar set of data obtained in 1962. Comparison of these data with simultaneously obtained results for the 6300 Å nightglow suggest that, on a gross scale, the excitation patterns for these two emissions are unrelated.

Author

1. Introduction

The nightglow emissions $[OI]_{32}$, $[OI]_{21}$ and N_2^+ (0-1) were monitored as part of NASA's Mobile Launch Expedition No. 1. A total of 63 nights of data were obtained from February 18, 1965 to May 2, 1965 over the latitude range 35°N to 60°S. This paper describes the results of the 5577 Å $[OI]_{32}$ nightglow observations made during the expedition and presents absolute calibrations for the 6300 Å $[OI]_{21}$ zenith observations which were reported earlier (Greenspan 1966).

2. Measurements

All nightglow measurements were performed with the three-color continuum-compensating photometers described by Filosofo et al. (1965). Four separate instruments were

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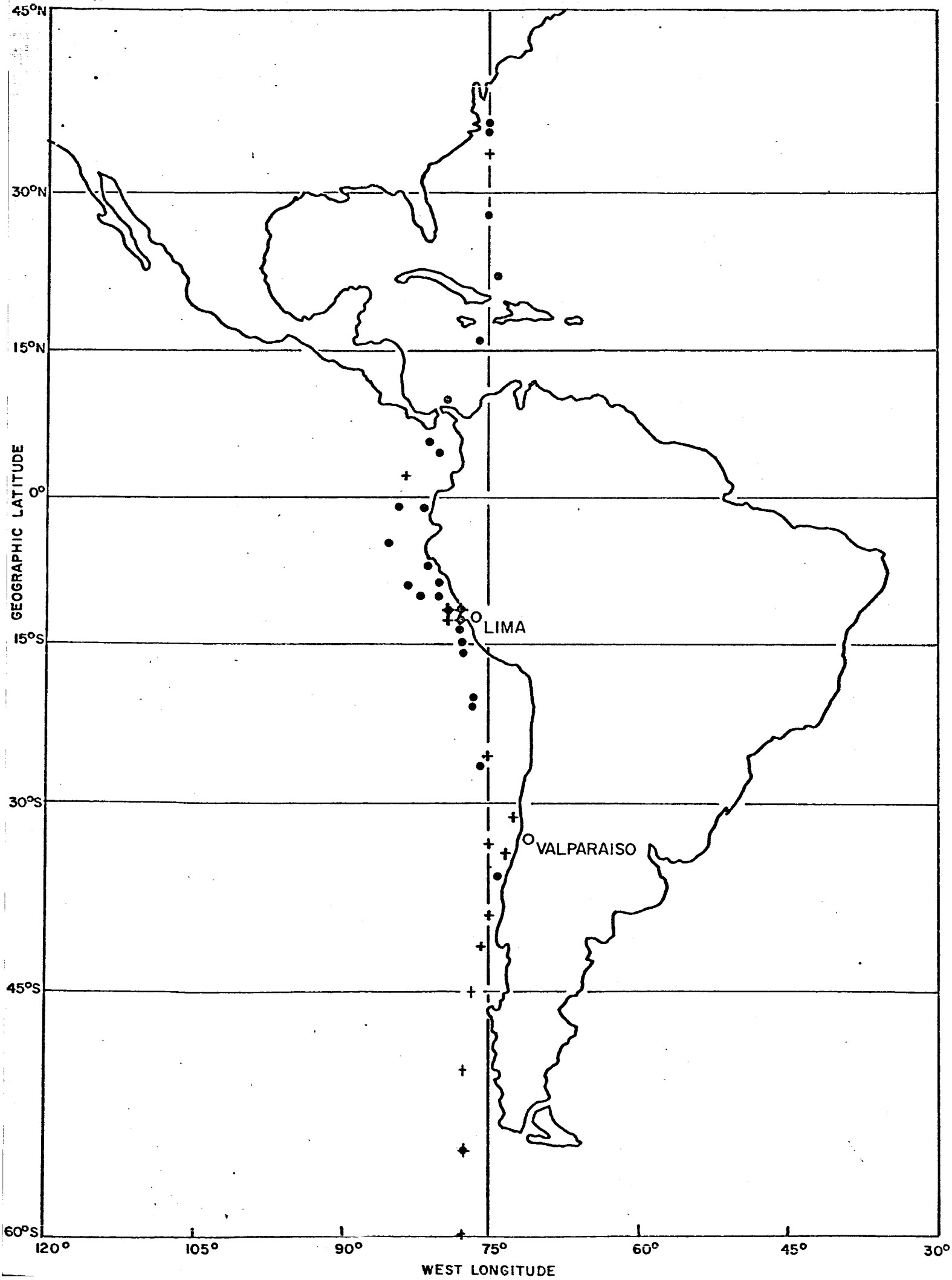
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installed on the flight deck of the U.S.N.S. Croatan. Two of these instruments monitored the zenith nightglow. Gimbal stabilization was employed in order to compensate for the ship's roll. One of these instruments functioned in the continuum subtracting mode which records the airglow emission intensity with less than 2 percent error due to the normal night sky continuum while the second instrument monitored the continuum brightness through a transmission band centered at a wavelength approximately 100 \AA below that of the emission line. The two remaining instruments were operated in the continuum subtracting mode and were inclined toward the bow of the ship at zenith angles of 5° and 15° . The lines of sight of these inclined instruments intersect the 300 km and 90 km levels of the atmosphere approximately 30 kilometers ahead of the ship, thus causing a stable localized enhancement to appear roughly one hour earlier on these instruments than on the zenith instrument, as a result of the ship's motion. The results reported here are derived mainly from observations with the zenith photometer operated in the continuum subtracting mode.

The mean locations of the Croatan on nights when airglow observations were made are shown in Figure 1. The dots indicate nights during which the best data were obtained and represent the data reported in this paper. The crosses indicate nights when cloud cover or moonlight produced substantial contamination.



3. Calibration

A general technique for the laboratory calibration of the continuum-compensating photometers was outlined by Filosofo et al. (1965). The following treats the calibration problem in a more explicit manner using a procedure similar to that described by Blacker and Gadsden (1965).

For completely effective continuum subtraction, the signal level V_D (volts) recorded for observation of the night sky in the continuum subtracting mode is:

$$V_D = E_\lambda T_\lambda P_\lambda \quad (1)$$

where E_λ is the emission line intensity in Rayleighs, T_λ is the absolute transmission of the interference filter at the emission line wavelength and P_λ is the combined photomultiplier and electronics sensitivity (volts/Rayleigh) at the emission line wavelength. For observations at normal incidence, of a calibrated standard light of brightness $SL(\lambda)$ in Rayleighs per Å, the signal level V_{SL} (volts) is given by:

$$V_{SL} = \int SL(\lambda) T(\lambda) P(\lambda) d\lambda \quad (2)$$

where $T(\lambda)$ is the absolute transmission profile of the filter in normal incidence and $P(\lambda)$ is the combined photomultiplier and electronics sensitivity profile. The integral is taken over the bandwidth of the filter at normal incidence. Since $P(\lambda) = P_\lambda$ is essentially constant over the bandwidth of the filter (approximately 25 Å), and since, for the calibration source employed in

this study, $SL(\lambda) = SL_{\lambda}$ over the same transmission band, we can combine Eqns. (1) and (2) obtaining

$$E_{\lambda}(\text{Rayleighs}) = \frac{V_D}{V_{SL}} \frac{SL_{\lambda}}{T_{\lambda}} \int T(\lambda) d\lambda. \quad (3)$$

Thus the laboratory calibrations only require the measurement of $\int T(\lambda) d\lambda$, T_{λ} and V_{SL} and the knowledge of SL_{λ} . It is to be understood that V_D and V_{SL} are measured at the same photometer sensitivity. A secondary standard light was employed in the field to maintain the system at laboratory sensitivity.

Measurements of V_{SL} were performed in our laboratories using a calibrated carbon-14 activated phosphor obtained on loan from the Environmental Science Services Administration (ESSA). This source, designated SL-Q, was calibrated by H. V. Blacker at the Fritz Peak airglow station in the manner described by Blacker and Gadsden (1965). The transmission of the filters was measured with a Cary-14 double-beam spectrophotometer. The calibration parameters and final results are given in Table 1. Since the standard light filled the photometers 3° field of view, no geometrical corrections were required.

The average 6300 \AA signal levels observed during the expedition (Greenspan 1966) were in the range 1-2 volts thus giving red line intensities in the range 65-130R which are consistent with values currently being reported in the literature. The 4278 \AA signal levels were near the dark current limit of the system suggesting N_2^+ intensities of only a few Rayleighs at most. Such low levels are normal (Chamberlain 1961, Yano 1966) for regions remote from the auroral zone, except at twilight. The 5577 \AA

Table 1
CALIBRATION PARAMETERS FOR THE ZENITH
CONTINUUM COMPENSATING PHOTOMETER

PARAMETER	4278 Å FILTER	6300 Å FILTER	5577 Å FILTER	CORRECTED* 5577 Å FILTER
T_λ (filter transmission at the emission wavelength)	0.445	0.470	0.150	0.380
SL_λ (source brightness at the emission wavelength)	$3.6^{+1.7}_{-1.3}$ R/Å	$10.8^{+0.2}_{-0.3}$ R/Å	3.6 R/Å	3.6 R/Å
$\int T(\lambda)d\lambda$ (integrated filter transmission)	10.8 Å	15.6 Å	9.8 Å	9.8 Å
V_{SL} (recorded signal level when observing calibration source)	5.6 ± 0.2 V	5.5 ± 0.2 V	$2.2^{+0.1}_{-0.3}$ V	$2.20^{+0.1}_{-0.3}$ V
$Q = \frac{SL_\lambda}{V_{SL}} \frac{1}{T_\lambda} \int T(\lambda)d\lambda$	16^{+8}_{-6} R/V	65 ± 4 R/V	107^{+17}_{-5} R/V	42^{+7}_{-2} R/V

*This column lists the calibration parameters obtained by assuming that the wavelength shift in the 5577 Å filter occurred subsequent to the completion of the 1965 Mobile Launch Expedition.

signal levels, however, lie in the range 3-8 volts which suggest average green line intensities from 300-850R, well above commonly observed mid-latitude and equatorial values. This anomaly results from the fact that the recently measured filter transmission peak is shifted 15 \AA toward the red from the emission line wavelength. This shift causes a decrease in the 5577 \AA transmission by a factor of 2.5. Thus, if the shift occurred after the observations were made, a value of $Q = 42 \text{ R/V}$ would be appropriate for the data. This calibration factor gives green line intensities in much better agreement with the normally observed values. Since the lack of preparation time precluded a pre-expedition calibration, we cannot resolve the time at which the filter shift occurred. As an alternative we therefore decided to obtain an approximate calibration for the green line through comparisons with data obtained during the time period encompassing the expedition for instruments at appropriate locations. Airglow data for times in this period were obtained aboard an AFCRL aircraft by Dr. T. Markham, (Velasquez 1966). For two nights in March and April, 5577 \AA intensities between 60-200 Rayleighs were observed (at somewhat different locations than the Croatan) suggesting that the lower calibration value of 42 Rayleighs/volt would be the more appropriate. When calibrated data from the Huancayo observatory (Velasquez 1966) become available, the calibration can be better determined. For the purpose of this paper we shall, however, employ the tentative value $Q(5577 \text{ \AA}) = 42$ Rayleighs/volt as derived in the last column in Table 1.

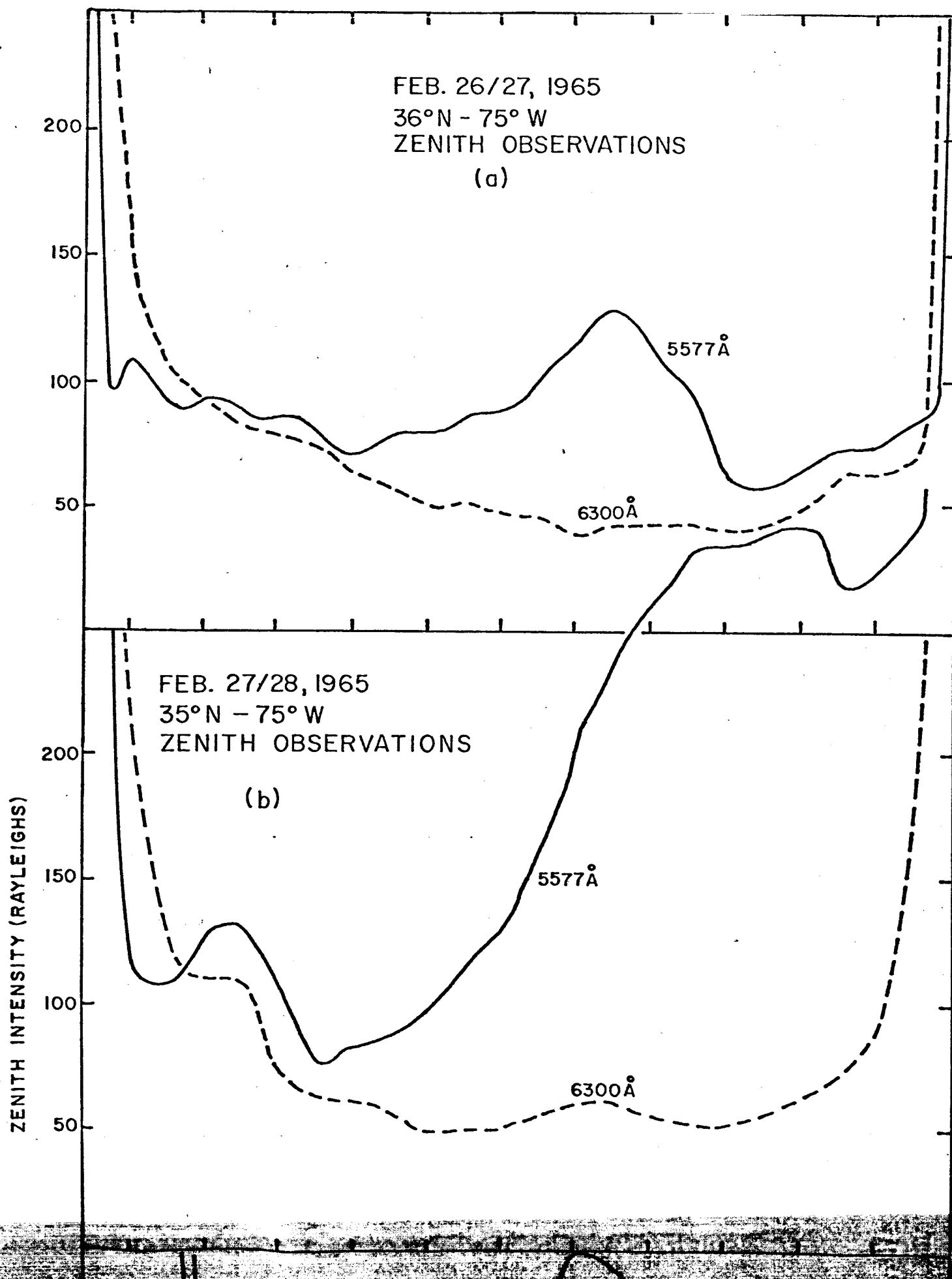
The 6300 Å calibration value of $Q(6300 \text{ Å}) = 65 \pm 4$ Rayleighs per volt can be applied directly to the results previously reported by Greenspan (1966).

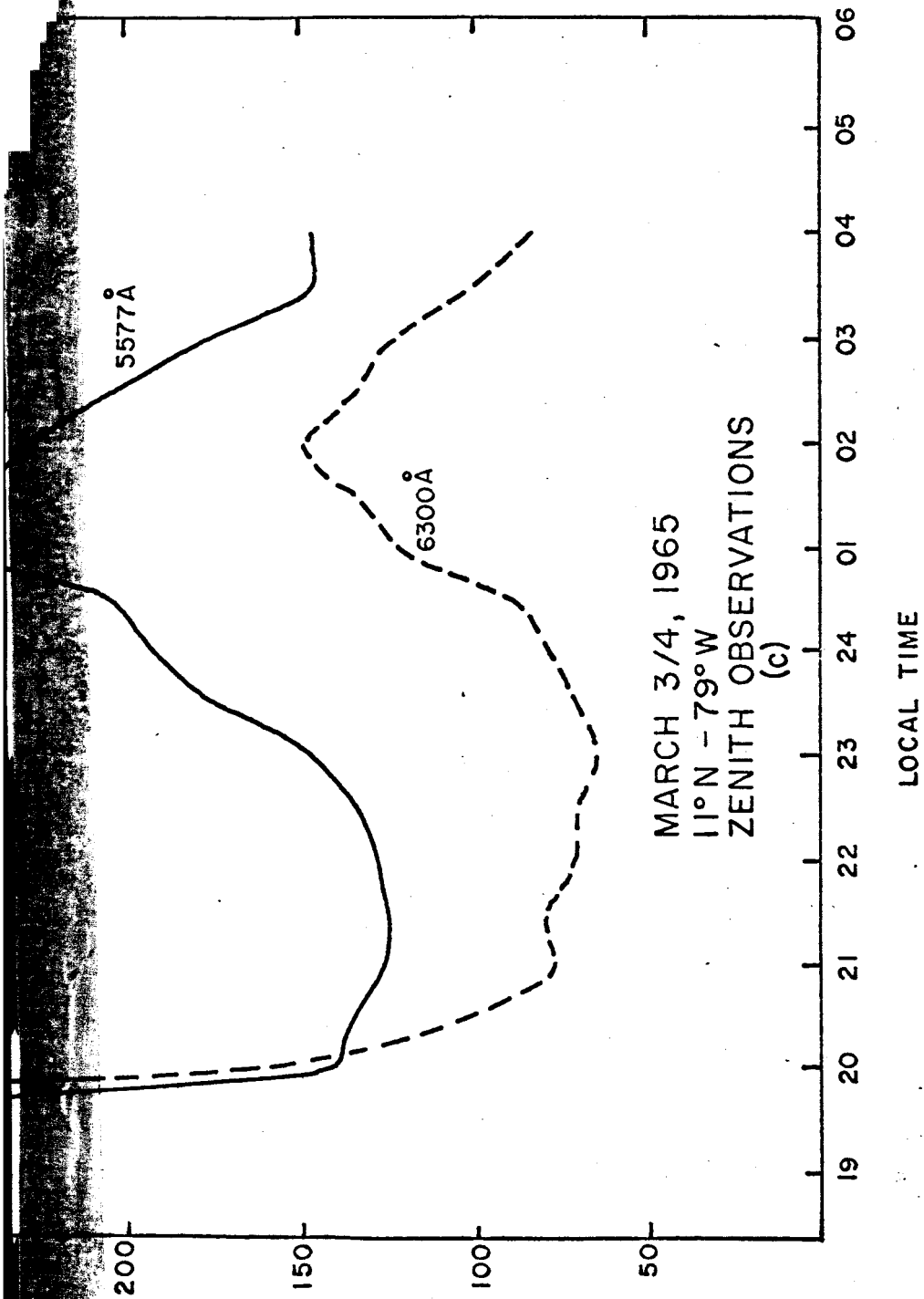
4. Diurnal Variations

Normally the 5577 Å zenith nightglow rapidly decreases in intensity during evening twilight, and reaches a relatively stable nighttime value of a few hundred Rayleighs. A rapid increase in brightness is observed at morning twilight.

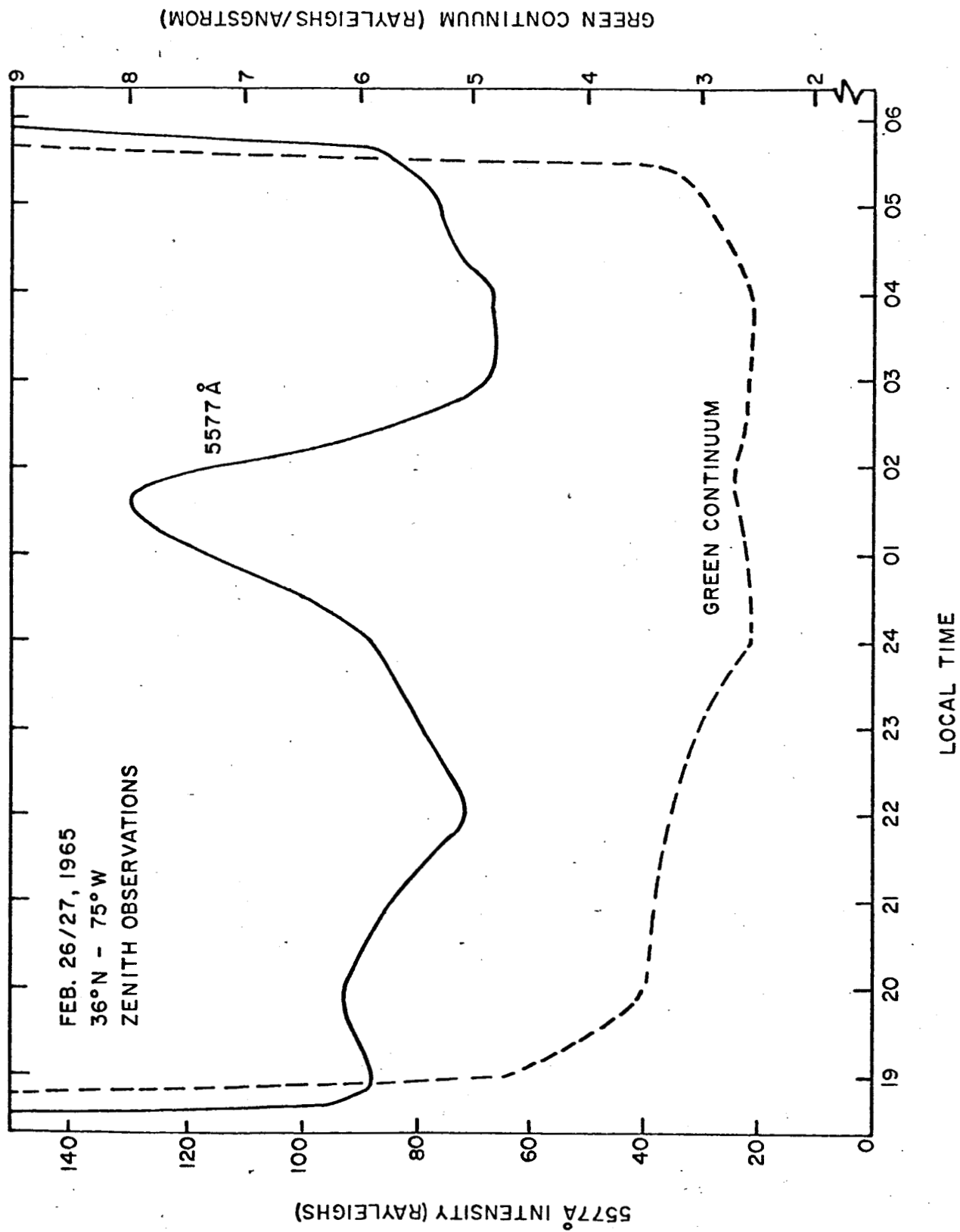
The 5577 Å brightness frequently exhibits a maxima in the middle of the night in temperate regions with a maximum intensity approximately 25 to 30 percent greater than the initial and final intensities (Silverman 1965). There seems to be little tendency for this maximum to occur at any particular time of the night (Chamberlain 1961) except possibly in the winter months (Barbier 1959). Several examples of 5577 Å enhancements were observed during this expedition. These occurred both with and without corresponding variations in the 6300 Å intensities. In general, the 5577 Å and 6300 Å data do not show any obvious signs of covariance. Examples of several 5577 Å enhancements are illustrated in Figure 2.

The 5577 Å $[OI]_{32}$ emission line and the green continuum form part of the green line covariance group (Chamberlain 1961). Comparison of the $[OI]_{32}$ data and the green continuum for several nights when strong midnight enhancements were observed do not however show any covariance, as illustrated in Figure 3.





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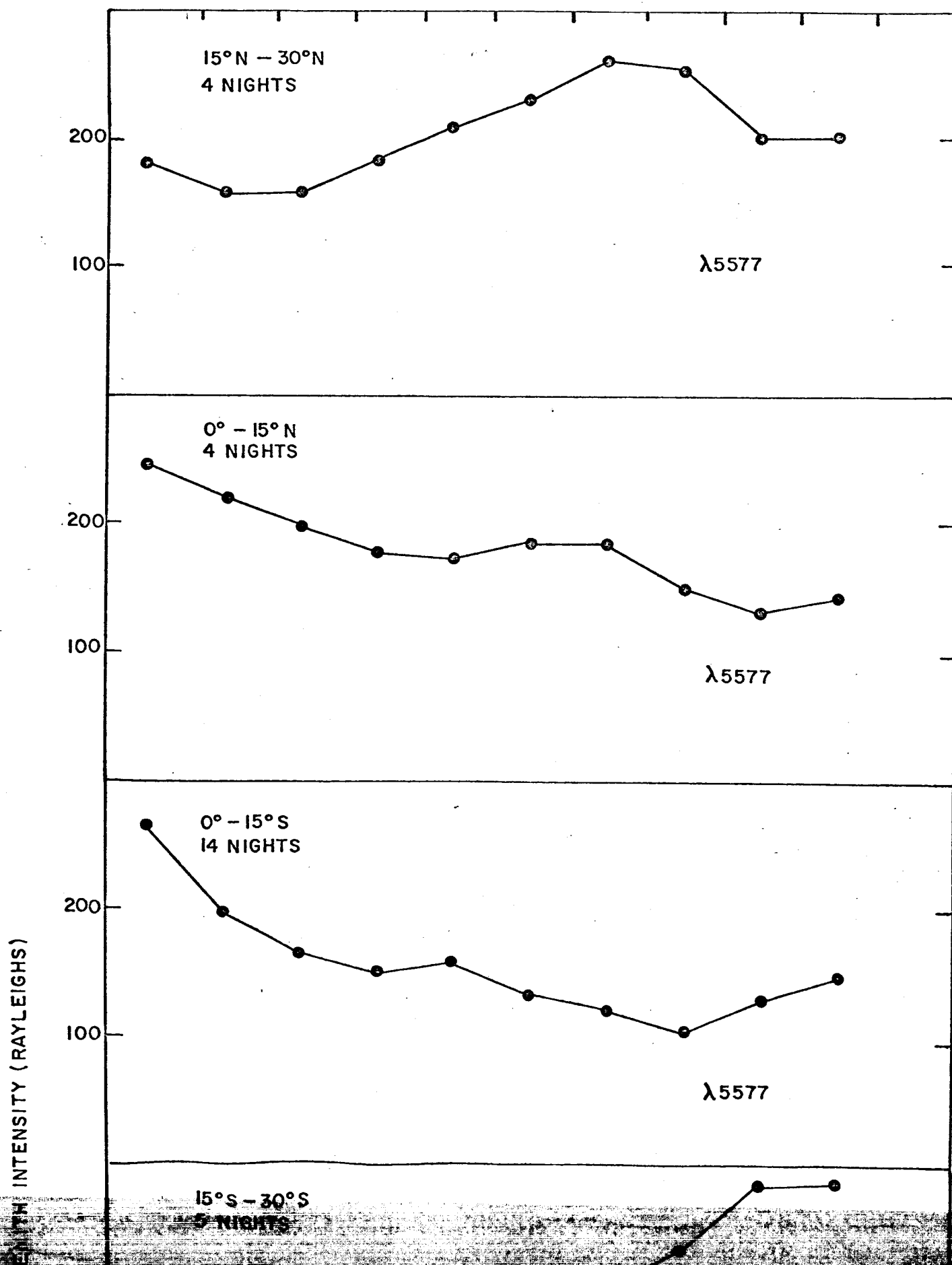
The average diurnal behavior of the 5577 Å intensity is shown in Figure 4 for several latitude ranges from 35°N to 60°S. These data suggest a symmetry about the geographic equator (the 6300 Å variations showed symmetry about the geomagnetic equator). In the latitude range 15°N to 15°S the variation is characterized by a slow decrease in intensity during the night. Late night increases are evident only poleward of this region.

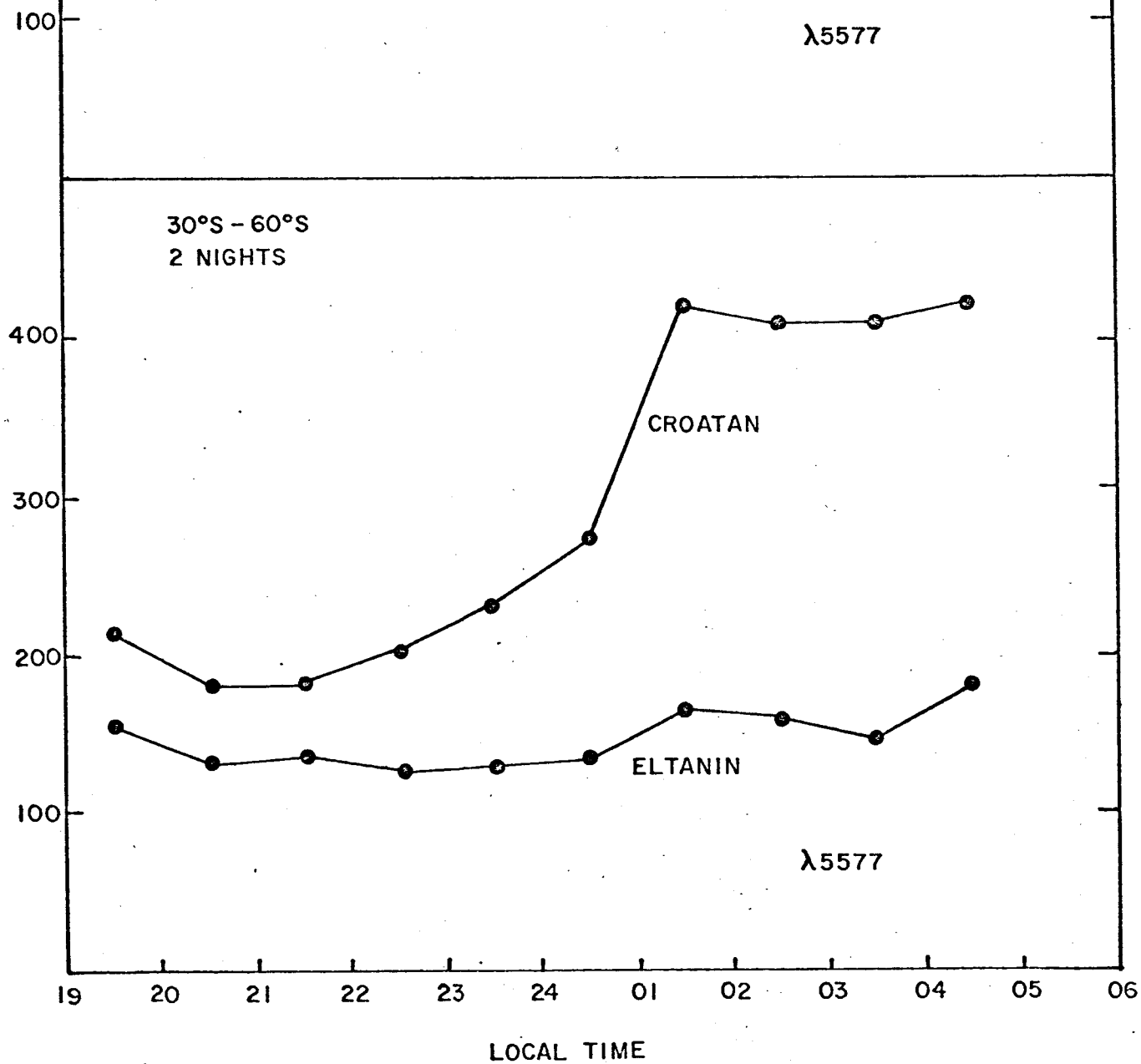
The average diurnal variation in the 5577 Å intensity as determined from 36 nights of data is shown in Figure 5 along with the corresponding data (Davis and Smith 1965) from a similar set of measurements performed in 1962 from the U.S.N.S. Eltanin. The absolute intensities and the magnitude of the variation are similar in both sets of data. Both exhibit a decrease in brightness following twilight with broad enhancements occurring during the night. The averaged 1962 data shows the enhancement occurring before midnight while the 1965 enhancements occur in the latter portion of the night.

5. Latitudinal Variations

The nightly average 5577 Å intensities for 10° latitude ranges have been calculated for each 5° of latitude from 35°N to 60°S. These data are shown in Figure 6 along with the corresponding results from the Eltanin. The Croatan results show an intensity minima at 5° south geographic latitude with increasing levels to approximately 30° north and south latitude where intensity maxima are observed. This symmetry was suggested

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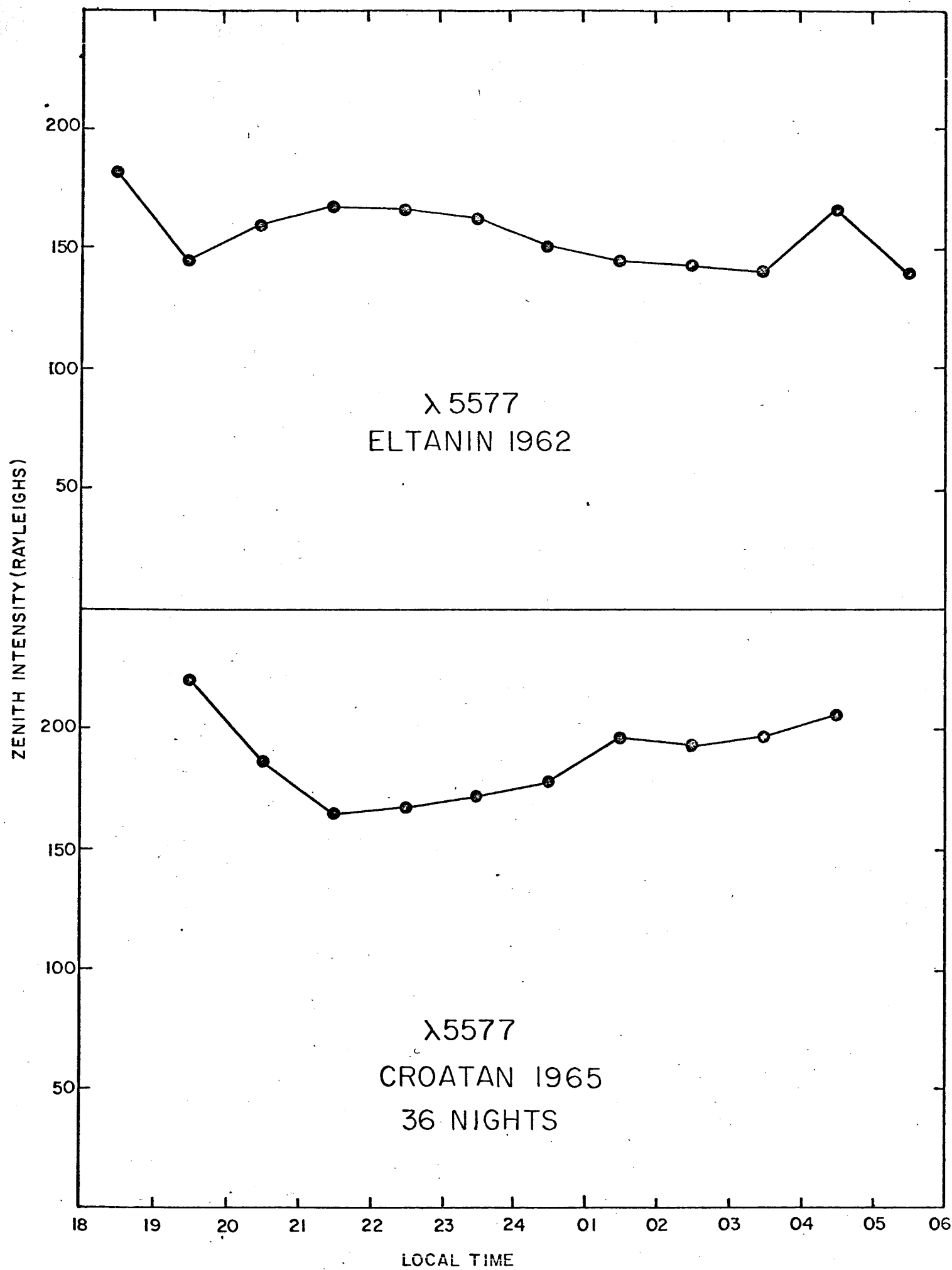


FIG. 5

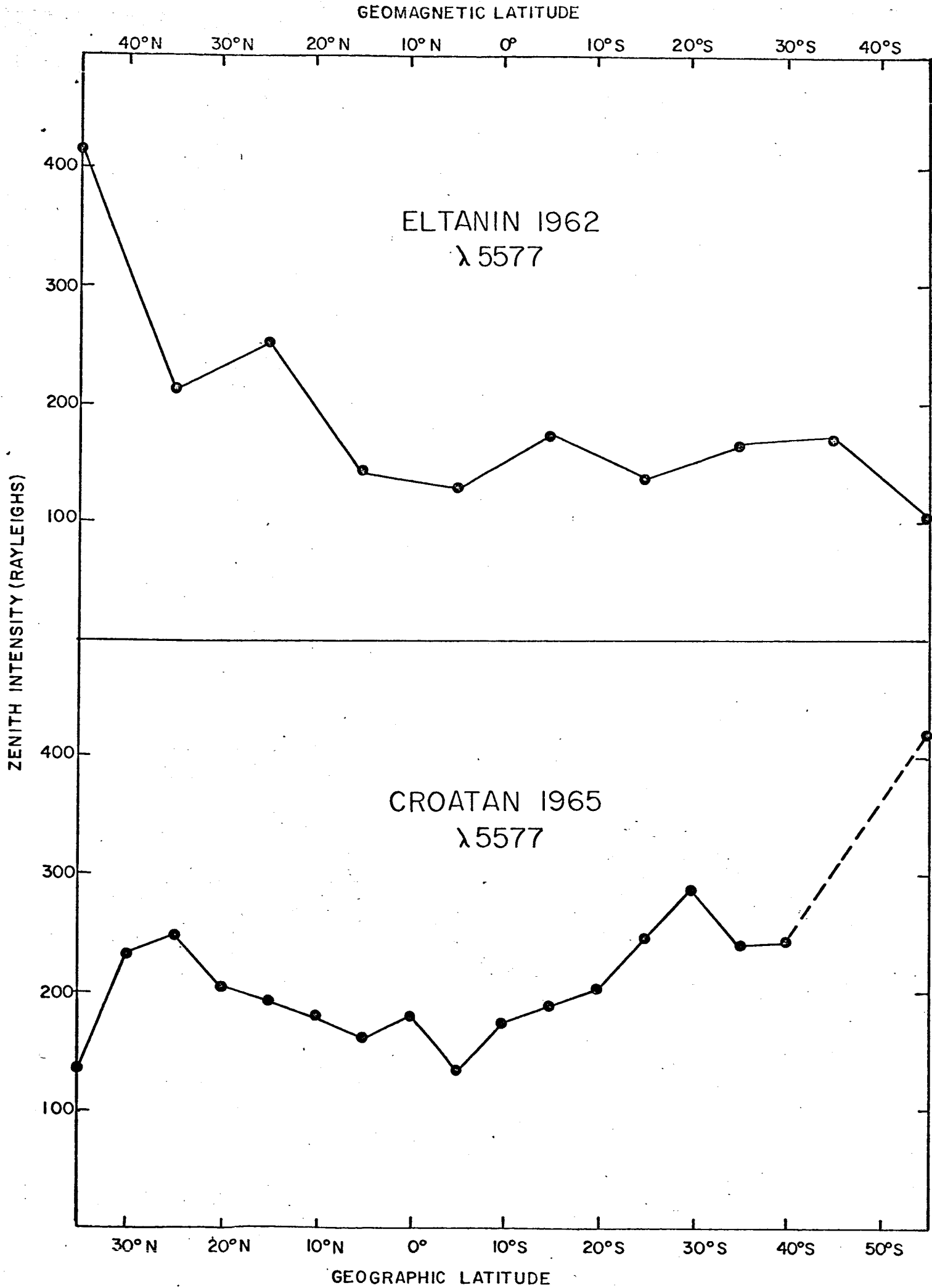


FIG. 6

earlier in Figure 4. Similar mid-latitude maxima are apparent in the Eltanin data and have been reported by Davis and Smith (1965). The current mid-latitude maxima appear to lie farther from the equator than in the 1962 results. Poleward of 30° latitude the two sets of data show an inverse correlation. The absolute intensities in the equatorial region are, however, in very good agreement supporting the low value for the calibration constant.

6. 5577 Å Airglow Cells

Figure 7 contains an isophote map constructed from the 36 nights of data used for this paper. The equatorial minima is evident as are the low early night intensity levels in the north and the high late night values in the south. There is also a distinct lack of closed cellular structure (Roach et al. 1958) in these data. It must be pointed out, however, that these isophotes represent averages of average intensities for many nights and include seasonal as well as night to night variations. Therefore, this map, as well as the 6300 Å isophote plot published earlier (Greenspan 1966) must only be interpreted in terms of the gross long term excitation pattern and may not have much direct relation to the excitation pattern for any single night.

It is of interest at this point to compare the 5577 Å isophote map with that previously given for the 6300 Å night-glow. Since both the diurnal and latitudinal variations are

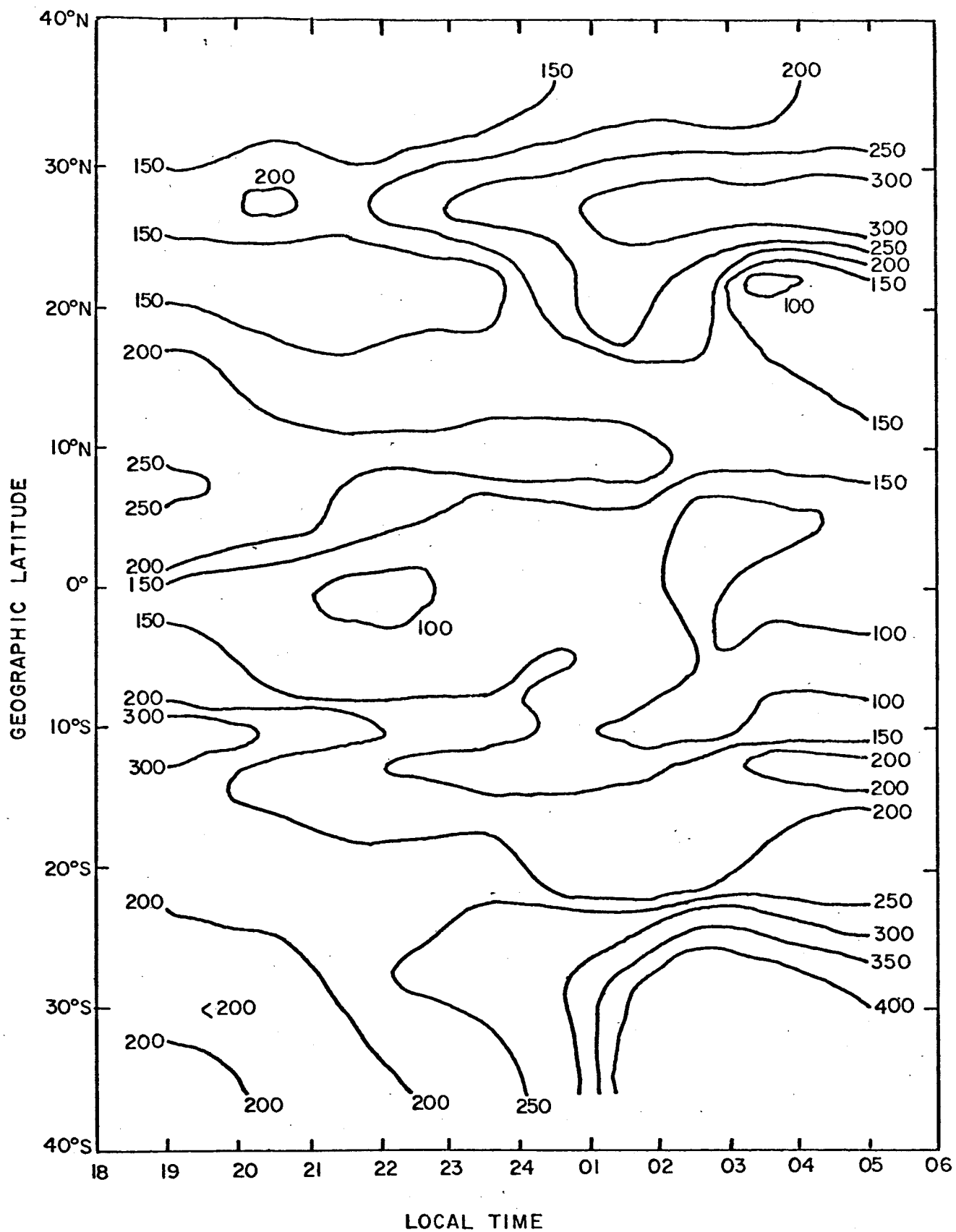


FIG. 7

contained in these maps and since no similarities are apparent, we can conclude that, on a gross scale, the two emissions are unrelated in the equatorial and mid-latitudes.

7. Variations with Geomagnetic Activity

The mean airglow intensities for 3 hour periods have been plotted against the corresponding planetary K_p indices (Lincoln 1965) using data from 36 nights of observation. No correlation between these parameters was evident. Hourly values of the 5577 Å intensity have also been plotted against the total magnetic field strength as measured at São José dos Campos, Brazil (Carrigan and Oliver 1965) for the same data. The results of this correlation attempt was also negative.

8. Conclusions

The 5577 Å zenith nightglow showed both quiet and disturbed behavior. In the latter case, the zenith intensity exhibited a broad enhancement in the late portion of the evening. The average diurnal behavior showed decreasing levels following evening twilight with enhanced emission after local midnight. Enhancements were strongest away from equatorial latitudes. No covariance was found between $[OI]_{32}$ emission and the green continuum. The total intensity variation in the diurnal average was of the same order of magnitude as that observed from the Eltanin in 1962.

Examples of direct, inverse and zero correlation are found between the 5577 Å and 6300 Å enhancements. The overall

results show little correlation with the 6300 Å data (Greenspan 1966) which were obtained simultaneously.

The diurnal behavior of the 5577 Å zenith intensity exhibits a symmetry about the geographic equator. In tropical latitudes the zenith intensities decrease uniformly throughout the night. Poleward of 15°N and 15°S geographic latitude, the post midnight enhancement becomes evident. From the very limited data available, it appears that this effect is strongest poleward of 30°S latitude.

The average nightly intensity of the 5577 Å nightglow shows a distinct equatorial minima at 5°S latitude with maxima near 30°N and 30°S latitude. This latitude variation is generally similar to that observed from the Eltanin, although the two sets of data show inverse correlation poleward of about 30°N and 30°S latitude.

When the data are presented on an isophote plot the general excitation pattern exhibits no relationship to the 6300 Å excitation pattern derived from data obtained at the same time.

No relationship appears to exist between the 5577 Å intensity and the planetary K_p index or the total magnetic field strength for these data.

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FIGURE CAPTIONS

- Fig. 1 Mean locations of the U.S.N.S. Croatan on Nights When Airglow Observations were Made
- Fig. 2 Examples of (a) a mid-night enhancement in the 5577 Å nightglow without corresponding 6300 Å variations (b) a late night enhancement in the 5577 Å nightglow without corresponding 6300 Å variations, and (c) mid-night enhancements in both the 5577 Å and 6300 Å nightglow.
- Fig. 3 Absence of Covariance Between the 5577 Å Emission Line and the Green Continuum
- Fig. 4 Diurnal Variations in the 5577 Å Zenith Airglow for Various Latitude Ranges
- Fig. 5 Average Diurnal Variation of the 5577 Å Zenith Intensity for the Latitude Range 35°N-60°S
- Fig. 6 Nightly Average 5577 Å Zenith Intensity as a Function of Latitude
- Fig. 7 Isophote Map Showing the 5577 Å Zenith Intensities, in Rayleighs, As Observed During NASA's 1965 Mobile Launch Expedition